Structural vibration characteristics of a pedestrian bridge by the 3D acceleration sensing of smart sensors and detailed 3D-FEM model

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Summary

In this study, we conducted fundamental study of structural health monitoring (SHM) by using 3-dimensional acceleration measurement and high resolution FE model analysis of a simple pedestrian overpass having an actual damage. Vibration measurement is performed on the pedestrian bridge by using Imote2 smart sensors. Plural vibration modes are identified from damped free vibration experiments. To reproduce the measured vibration characteristics with satisfactory accuracy for SHM in the analytical model, it is necessary to appropriately model the boundary conditions and secondary members. In this study, modelling of connecting part of main girder and stairs is examined in several patterns. Then, appropriate method of detailed FE modelling is discussed by comparing natural vibration characteristics from eigenvalue analysis.

Keywords: smart sensors; vibration monitoring; modal shape; FEM modelling; pedestrian bridge.

1. Introduction

In this study, we conducted fundamental study of SHM by using 3D smart acceleration sensors [1], [2] and high resolution FE model of a pedestrian bridge which has 2 main steel girders. Not only natural frequencies but also modal shapes are compared to the result of multipoint measurement in construction of the detailed analytical model. Moreover to improve accuracy of the modelling, boundary condition of main girder and stairs is updated and its applicability was examined whether the measured values can be reproduced.

2. The vibration measurement experiment on pedestrian bridge

This bridge is a steel structure with single span of 18.48m, width of 1.5m. Its main superstructure is composed by the steel floor deck on two C-shaped steel girders. One girder has deformation and crack at the web.

The vibration characteristics (natural frequency, damping ratio, mode shape) of 1st ~ 6th mode that were identified from the measurement were shown in table 1. From table 1 the identified mode shapes are summarized as follows. In the 1st mode, the modal amplitude most predominates in longitudinal direction although vertical component is also caused by human excitation. The 2nd mode was vertical symmetric bending mode. The 3rd mode is vibration in transversal and vertical direction. In y-z plane, red line and green line have amplitudes in different directions. This difference is explained as the stairs side girder (red line) is restrained in horizontal direction by the stair. The 4th mode is torsional vibration mode.

Fig. 1: Pedestrian bridge

The mode has also an amplitude component in the transversal direction. The 5th mode was asymmetric bending mode with an amplitude in the transversal direction. The 6th mode was torsional mode. In addition, in x-y plane, it can be confirmed that the rotational mode around the z-axis.

3. Numerical model construction of pedestrian bridge and the natural frequency vibration analysis

3.1 Modelled without stairs

Analysis values has a big difference to measurement values. Especially 1st mode has about 15% and modal shape does not correspond to experimental result. Also, the 3rd mode of the measurement has not obtained. The cause of these differences is considered that the effect of restraint by stairs.

3.2 Modelled connected as pin

The torsional mode has difference of about 10%. However, the other modes are can be modelled within about 5% error of natural frequencies. By modelling the stairs main girder is restricted, horizontal mode of transversal direction is disappeared and torsional mode is appeared. In horizontal mode of longitudinal direction, it is possible to confirm the vertical amplitude.

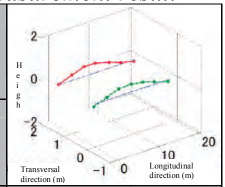
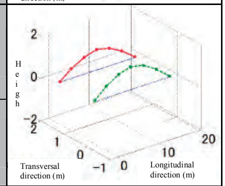
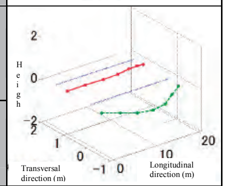
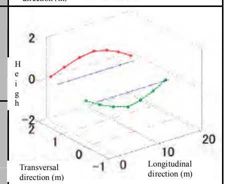
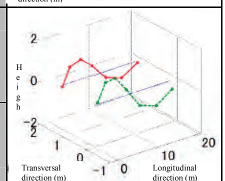
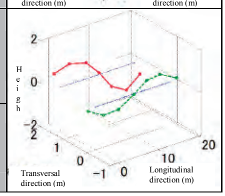
3.3 Modelled connected as completely fixed

Compared with the pin model, natural frequency increased by increasing restraint of main girder. Many of analysis values is greater than measured values, it is desirable that boundary condition are adopted pin connection. Moreover, by reducing the spring stiffness of the translational direction, it considered that can reproduce the measured values.

4. Conclusion

The results of three-dimensional measurement, it was possible to identified six vibration characteristics. To confirm effect of the mode shapes by the damage, it is necessary to perform measurement of after repair under same condition of this measurement.

Table 1: Measurement result

1st	frequency 4.2Hz	
	damping 0.0060	
2nd	frequency 4.9Hz	
	damping 0.0058	
3rd	frequency 7.8Hz	
	damping 0.0036	
4th	frequency 9.8Hz	
	damping 0.0018	
5th	frequency 15.5Hz	
	damping 0.0019	
6th	frequency 20.9Hz	
	damping 0.0015	

The model with stairs which are connected at both end of one girder shows better accordance with measurement modal characteristics in plural modes. It was found that boundary conditions of main girder and stairs is dominated by stiffness of transversal direction, and changes in other translation directions and rotational stiffness little effect. On the other hand from the results of this study, analytical results were not consistent with measured results perfectly in plural natural mode all together. It is necessary to review the analytical model in detailed member and material parameters.

5. References

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